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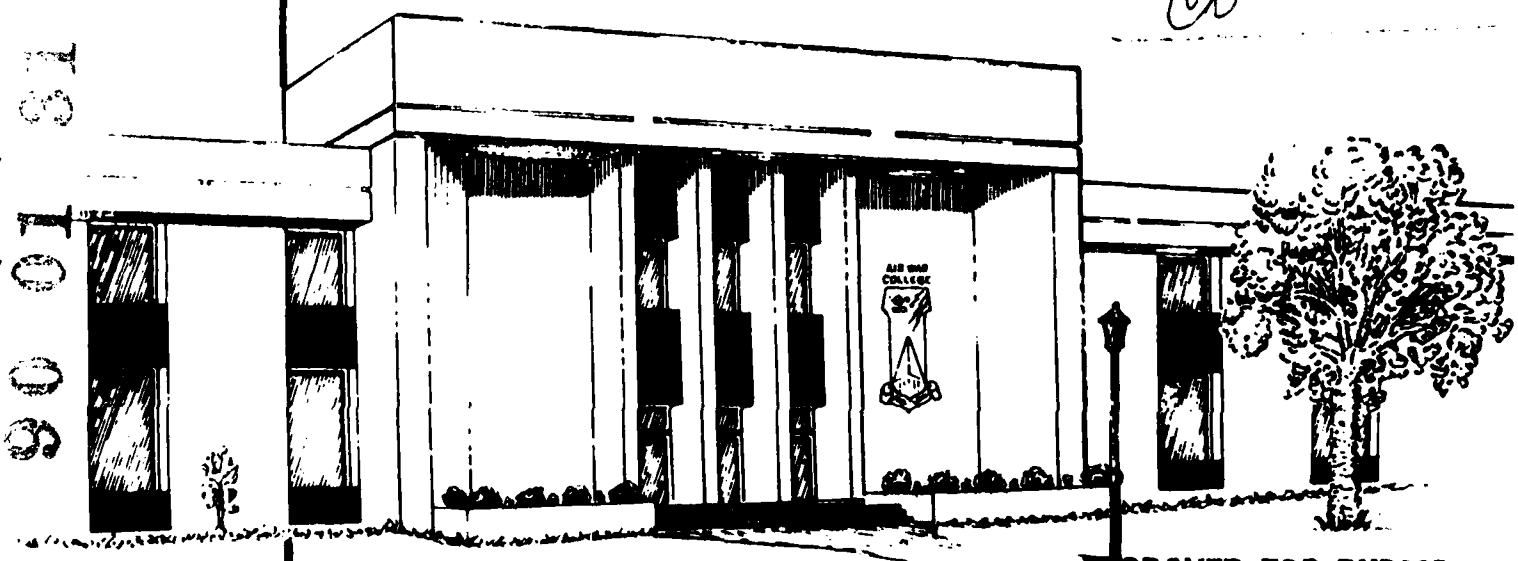
AIR WAR COLLEGE

RESEARCH REPORT

WEATHER SUPPORT TO THE AIR TASKING ORDER

LIEUTENANT COLONEL THOMAS E. SIELAND

1989



AIR UNIVERSITY
UNITED STATES AIR FORCE
MAXWELL AIR FORCE BASE, ALABAMA

AIR WAR COLLEGE
AIR UNIVERSITY

WEATHER SUPPORT TO THE AIR TASKING ORDER

by

Thomas E. Sieland
Lieutenant Colonel, USAF

A DEFENSE ANALYTICAL STUDY SUBMITTED TO THE FACULTY

IN

FULFILLMENT OF THE CURRICULUM

REQUIREMENT

Advisor:Colonel Bryant P. Culberson

MAXWELL AIR FORCE BASE, ALABAMA

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EXECUTIVE SUMMARY

TITLE: Weather Support to the Air Tasking Order

AUTHOR: Thomas E. Sieland, Lieutenant Colonel, USAF

Historical information on weather support to the tasking of precision guided munitions (PGMs) from the author's experinces in Vietnam and Korea lead to a discussion of current weather support requirements for the air tasking order (ATO) at the numbered air force level of combat operations. The ATO discussion is followed by a description of computer generated, weather tactical decision aids (TDAs) used to currently support the employment of PGMs and tactical acquisition systems (TASs). The author then analyzes the weather sensitivities of PGMs and TASs to reveal that the TDA computer programs cannot be used to support the number of targets requiring weather information in the air tasking order process. An analysis of Air Weather Service capabilities and programs shows that quality weather data is available, however, to support the proposed Electro-Optical TDA programs to provide weather information to combat planners. The author recommends the actions necessary to develop the best weather support programs to provide the detailed weather data needed for tasking electro-optical weapon systems in the air tasking order.

BIOGRAPHICAL SKETCH

Lieutenant Colonel Thomas E. Sieland (B.S., Florida State University, M.S., University of Michigan, PhD, Texas A&M University) enlisted in the Air Force in January 1960 and received his commission via the Airman Education and Commissioning Program in 1968. He became interested in weather support to the tasking of precision guided munitions (PGMs) during his tour as Staff Weather Officer (SWO) to the Commander of 7th Air Force (7 AF) in Vietnam during the bombing of North Vietnam in 1972. Following his tour in Vietnam, he served in a variety of weather jobs at all levels of operations from detachment to squadron through wing to the numbered air force level. In 1986, he was once again assigned as the SWO to 7 AF in the Republic of Korea where he experienced more problems with weather support to the tasking of PGMs in the ATO for 7 AF. He is a graduate of Squadron Officer School(1973), Air Command and Staff College(1981), and the Air War College, class of 1989.

SECTION I

INTRODUCTION

Background

My first involvement with providing weather support to the tasking of electro-optical(E-O) weapons was in Vietnam. In the Spring of 1972, I was the Assistant Staff Weather Officer (ASWO) to the 7th Air Force Commander (7AF/CC) when the US resumed bombing military targets in North Vietnam. As the ASWO, I was responsible for providing weather information to the combat planners for their use in building an air tasking order (ATO) that included the employment of laser guided bombs (LGBs) against high value targets in North Vietnam. However, since I didn't have any experience providing this type of support, I realized immediately I had a lot to learn. First and foremost, I had to learn everything I could about how LGBs worked, so I could provide meaningful weather information to the planners. Therefore, I spent numerous hours with the weaponeers, learning how the laser designator system worked and how the aircrews would actually employ the weapons. Once I understood how things worked, I was able to tailor the weather briefings we gave to the 7 AF/CC and his staff to zero in on weather elements that affected the employment of LGBs.

Every afternoon we prepared a detailed weather briefing

for the 7 AF/CC, intelligence, and combat plans staff so they could decide whether or not to include LGBs in the ATO for the next day. This system worked well for two reasons. First, the strike flights were only dropping between 10 and 20 LGBs on a given mission, and second, the targets were all in the same general area of North Vietnam.

The next time I was involved with the problem of providing weather support to combat planners was in 1986 when I was assigned to the Republic of Korea as the SWO to 7 AF. This time, however, the problem was even more complex because we had a wider variety of E-O weapon systems (also referred to as precision guided munitions (PGMs)) and new target acquisition systems (TASs) in the Air Force inventory. In addition, these PGMs and TASs now spanned the electromagnetic spectrum from millimeter and microwave, all the way to the visual end of the spectrum. Table 1 contains a list of these weapons.(1:3) As we will see later, these systems have slightly different weather sensitivities which affects their employment and which further complicates planning for their use. I also found that my 7 AF Weather Support Unit (WSU) used basically the same weather equipment and data we had in our WSU in Vietnam some 15 years earlier.

Looking to the future, the Air Weather Service (AWS) will field the new computer driven Automated Weather Distribution System (AWDS) in the next few years that will

TABLE 1. PGMs and TASs in the Air Force Inventory.

TELEVISION (0.4 to 0.74 microns)

TV Maverick (AGM-65A and 65-B)
Modular Guided Glide Bomb (GBU-15/TV)
PAVE SPIKE TV E-O Viewing Systems (EVS)
Steerable TV

PASSIVE INFRARED (8 to 12 microns)

PAVE TACK FLIR (Forward Looking Infrared)
IR Maverick (AGM-65D, AGM 65G)
Modular Guided Glide Bomb (GBU-15/IR)
LANTIRN (Low Altitude Navigation and Targeting Infrared for Night)
E-O Viewing System Forward Looking Infrared

LASER (1.06 microns)

Laser Guided Bombs (GBU-10,12, & 16)
Low-Level Laser Guided Bomb (GBU -24)
PAVE PENNY
PAVE TACK Target Designator
PAVE SPIKE Target Designator
LANTIRN Target Designator
Ground Level Laser Designator (GLLD)
Laser Target Designator (LTD)
Modular Universal Laser Equipment (MULE)

PASSIVE MILLIMETER (6.1mm to 1.0 cm)

Antiradiation Missile (AGM-78)
Shrike (AGM-45A)
High-Speed Antiradiation Missile (HARM)

bring the WSU of the 1970s into the automated age of the 1990s. Also, in the late 1970s AWS had the Air Force Geophysics Laboratory develop computer programs to provide detailed weather support to the crews responsible for employing E-O weapon systems. However, AWS has not yet developed a system to support the combat planners who have to make the critical decisions on whether or not to task the

employment of these very expensive, highly weather-sensitive weapon systems. In developing the ATO, combat planners require weather information to assist them in deciding whether or not to task the employment of E-O weapon systems against high value targets(2:9-18). Furthermore, this information is needed as much as 36 to 48 hours in advance of the time the ATO will be executed by the flying wings. This brings me to the purpose of my Defense Analytical Study.

I will analyze the problem to determine what is the best method and format for providing weather information to make the combat planner's job more effective. I will begin by examining the sequence of events in the ATO process to determine what weather information is needed at each step in the process. Next, I will review what exists in the way of current computer generated tactical decision aids (TDAs) used to brief air crews who employ E-O weapons. I will then use this information to analyze whether we can use these TDA programs to support the ATO process or whether we need to develop new programs for that purpose. Following that, I will analyze current and future AWS capabilities to provide the required weather information to support the ATO process. Finally, I will summarize the key results of the analysis from each section, and develop what I believe is the best concept for providing weather support to the ATO and conclude with some recommendations.

Assumptions

1. The Tactical Air Forces will incorporate Electro-Optical Tactical Decision Aids (EOTDAs) and target weather data bases into their command and control computer systems.

2. Air Weather Service will continue to fund the development of EOTDAs and target weather data bases.

3. Satellite communication links will be available to send target weather data bases from Air Force Global Weather Central to the theater weather support units.

4. Manpower authorizations at weather support units will neither increase nor decrease.

Limitations

Since the Relocatable Window Model (RWM) is not yet on line at the Air Force Global Weather Central, I had to use the reliability of output data from the Global Spectral Model (GSM) to infer a comparable reliability of model output performance from the RWM. This is logical to do because the RWM basically models, at higher resolution, the same physical processes as the GSM.

SECTION II

THE AIR TASKING ORDER PROCESS

The primary mission of aerospace forces is to obtain air superiority and support the Army campaign by attacking the enemy's forces and capability to fight.(3:1-3) This mission includes air operations like close air support, offensive and defensive counter air, and interdiction. To accomplish their mission, the Air Force will have to destroy numerous high priority, high value enemy targets such as hardened command and control facilities, electronic warfare nodes, ground control intercept sites, air fields, and aircraft shelters. Attacking forces will need to use the pinpoint accuracy of precision guided munitions (PGMs) to ensure these high value targets are efficiently destroyed. In fact General Russ, Commander of Tactical Air Command, addressed this issue in his recent talk at the Air War College when he basically said these very expensive PGMs must be used primarily against high value targets that are comparable in cost to our effort.

The key point here is that we cannot squander these weapons by trying to attack targets where the weather is so bad the crews can't acquire the target. In these cases, the crews may expend these expensive weapons against secondary targets of much less value. Therefore, combat planners and crews must have the best information available to ensure they can both accomplish their missions.

But here lies the crux of the problem--PGMs are very accurate, but they are also greatly affected by atmospheric conditions. Therefore, it is imperative that combat planners task the use of PGMs in the ATO judiciously. I believe judicious tasking can be accomplished by taking into consideration the affects weather will have on the ability of the weapon system to acquire and lock-on the target, as well as the affect weather will have on the tactics used to attack the target. Let's take a look at the ATO process and see where weather is a player.

Review of the Air Tasking Order Process

I was fortunate to have the advice of Lt Col Gary Hawse, Chief of Combat Plans for 7 AF, while he was at Maxwell AFB attending a course in contingency planning. Since I knew Lt Col Hawse from my days as SWO to 7 AF in the Republic of Korea, I asked him to work with me on analyzing the ATO process and determining at which points in the process his planners would need weather support. The information that follows was derived from that interview.

We started by looking at the heart of the ATO process, which is shown in Figure 1(4:15). By looking at Figure 1, we can see that the time interval from the beginning of the allocation (tasking) portion of the ATO cycle, which begins with target development on DAY 1/1800, to the end of the cycle, on DAY 2/1800, is approximately 24 hours. At the end

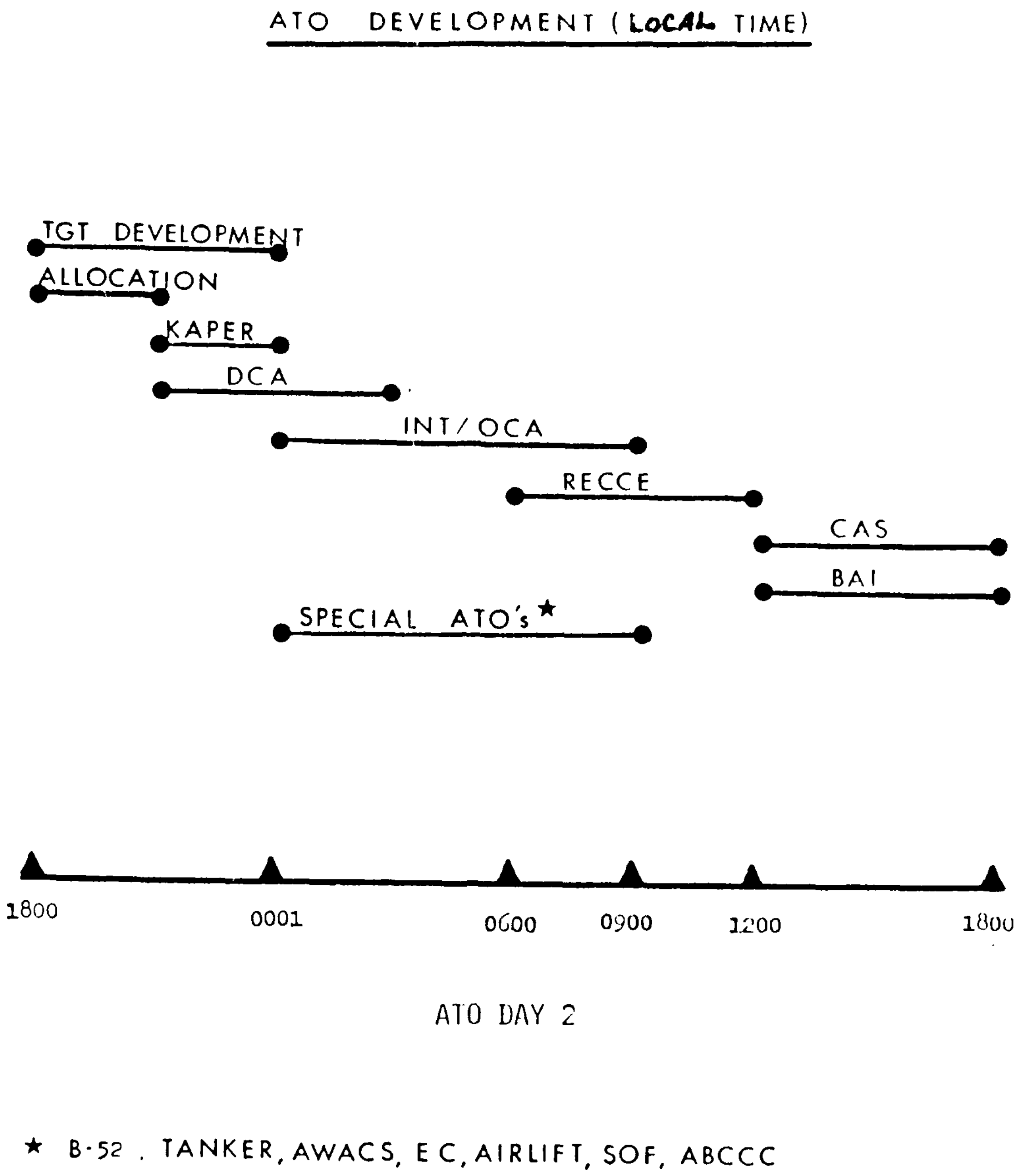

Figure 1. The ATO Tasking Cycle (all time are local times).

of the tasking cycle, the ATO is sent to the flying wings to be executed beginning on Day 3 at 0600. Consequently, weather information is needed as much as 36 to 48 hours prior to the time a mission may be flown. I should note here that Lt Col Hawse also checked with members of his class from other commands and confirmed that this set of timelines also applied to the ATO process for United States Air Forces Europe.

Next, we discussed what percentage of the sorties tasked in the 7 AF ATO would employ PGMs. Based on Lt Col Hawse's experience in Korea and elsewhere, he concluded that somewhere between five and ten percent of the approximately 1500 daily sorties in the 7 AF ATO would call for PGMs, which works out to be about 75 to 150 sorties. This gave me some working figures to use in determining how large the workload will be on the weatherman when it comes to producing products to support the ATO process. Then we looked at the various steps in the ATO process to determine at which points the combat planners need weather information to assist them in making decisions on whether or not to employ PGMs.

Weather Decision Points in the ATO Process

Based on the steps in Figure 1, we determined the first weather briefing is required at Day 1/1800 during the target development phase of the ATO (24 hours before the ATO will

be sent to the flying wings). We also agreed the weather briefing for the planners and intelligence people should be a general, broad scale weather forecast for the entire area of operations. However, since most of the high value targets will be in the interdiction or offensive counter air (IN/OCA) portion of the ATO, we also determined that at target development time, the planners would be able to give the weather man a list of targets that will be prime candidates for the employment of PGMs. Therefore, the weather support unit (WSU) will know how many and which targets will need more detailed weather information later in the process. In addition, the weather support unit will have about 6 hours to develop the detailed weather information the planners would need by the start of the INT/OCA step in the ATO cycle. Although we discussed the possibility of tasking PGMs during the close air support and battlefield air interdiction (CAS/BAI) portion of the ATO, we agreed CAS/BAI targets would normally fall into the realm of immediate air requests. Therefore, planners would not normally require detailed weather support to make these tasking decisions. At the beginning of the INT/OCA step, the planners will be looking for detailed weather information in the format of specific weather thresholds to help them make their decisions.

Weather Thresholds for Tasking PGMs

Durin, our interview, I asked Lt Col Hawse if there were unambiguous maximum or minimum weather conditions or thresholds the combat planners could identify above which the planners would know they could task precision guided munitions, and below which they couldn't. He said it was not a simple matter, because the tactics used to attack a target will vary based on the surface-to-air threat around the target. Thus two identical targets with different surface-to-air threats would require different minimum weather conditions to successfully employ PGMs. For example, if the threat is great, the planners would want a ceiling and visibility of at least 5,000 feet and 5 miles or more before they would task a PGM against the target. On the other hand, for a target with a lower threat the aircraft could fly closer and the mission could be tasked with a ceiling and visibility of 3,000 feet and 3 miles or better. Figure 2 shows what we were talking about.

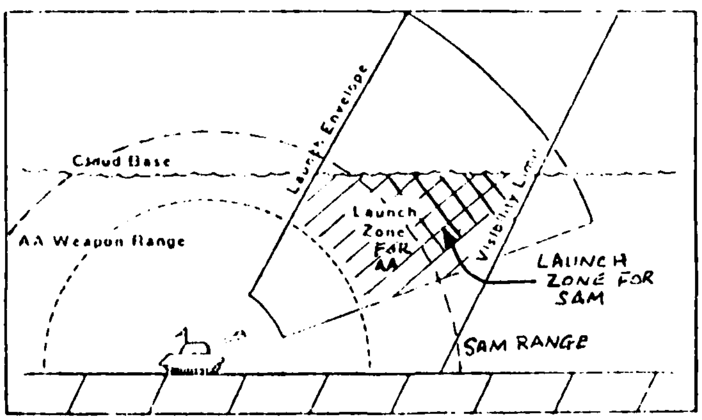

Figure 2. The Effects of Weather on an Attack Profile.

As you can see, if the surface-to-air threat increased and the weather stayed constant, the launch zone or employment envelope will decrease in size. So much depends on the target environment. It would be very difficult to develop a set of unambiguous weather thresholds that will apply across the board. However, there is an absolute lower limit below which no PGM can be successfully employed and this varies for each weapon system.(5:87) As a result, we can only define an unambiguous lower threshold against which we can compare the weather forecasts that will tell combat planners not to task the use of PGMs in that situation.

Methods for Providing Weather Information

Lt Col Hawse and I also discussed several methods by which weather information could be given to the planners. First of all, we could simply give the planners detailed target weather information such as cloud layers and amounts, surface visibility, and sensible weather such as precipitation, dust, haze, etc. The planners would then have to make their decisions based on this information. We both agreed, however, that this method placed too much of an interpretation burden on the planners. If, on the other hand, computer programs existed on the host (numbered air force or equivalent) command and control computers to interpret weather information for the planners the problem could be solved. In such a case, the weather forecasters

could provide a target weather data base suitable for computing a planning type Electro-Optical Tactical Decision Aid (EOTDA) program and let the planners run the programs to produce the output they need. In fact, as I later found, Air Weather Service has tasked the Air Force Systems Command to develop EOTDA programs in the next few years.

Another method we discussed was one in which the weather support unit would provide the planners a single acquisition and lock-on range for selected PGMs by target candidate. Although this method would give the planners what they need to make decisions when the weather was very good or very bad, it wouldn't really help them with the tough decisions when weather was on the margin. This led us to the idea of developing a method that we believe would provide better, more useful information to the planners.

After discussing the various options, we agreed that the best type of product the weather forecaster, or a computer, could provide would be a printout for each target candidate that gave the best and worst conditions expected in the target area, along with some degree of confidence that those weather conditions would occur. For example, the best weather conditions we expect to have in the target area is ceiling of at least 5,000 feet and visibility of 5 miles. The worst condition we expect is a ceiling of at least 3,000 feet and a visibility of 3 miles or more. Then we tell the planners we are 70 percent confident of having the best

conditions and 30 percent confident of having the worst conditions. In addition, the product would include the maximum and minimum acquisition and lock-on ranges based on the best and worst conditions. For example, to hit target X with a TV Maverick missile, you could expect to acquire the target at a minimum range of 2.5 miles and a maximum range of 4 miles, and be able to lock-on the target at a range of 2 to 3 miles. This way the planners have a range of values to work with and could take other factors into consideration when making the final decision on whether or not to task the weapon.

The methods described above would be very useful when, as often is the case, the theater commander wants to strike a particular target that is critical to his overall plan. In this case, the planners could be influenced to task a mission even though the weather is below the normal engagement zone. However, this method of presenting the weather information would also give the planners a general idea of the degree of marginality (i.e. poor to marginal in the case of acquisition ranges of 1.5 to 2.5 miles and marginal to fair for ranges of 2.5 to 4 miles). This method and format will also give the planners the ability to quickly determine which targets should have no weather problems, and which are unworkable. The planners could then spend the bulk of their time making decisions on the rest of the targets. If needed, the planners could also confer with

the weatherman to look for more detail or even request updated figures on acquisition and lock-on ranges. Now that we have looked at PGM weather thresholds and the ATO process, it will be necessary to investigate tactical decision aids and their importance in the targeting process.

SECTION III

TACTICAL DECISION AIDS (TDAs) FOR ELECTRO-OPTICAL WEAPONS

The purpose of this section is to give the reader a basic appreciation for the weather sensitivities of various precision guided munitions (PGMs) and target acquisition systems (TASs). Recall that TASs are TV or imaging infrared TV viewing systems that allows the weapon systems officer in the aircraft to see the target scene, find the target, and designate the target with a laser beam. For a more detailed treatment of the subject, I recommend reading AWS/TN-87/003, Weather Sensitivities of Electrooptical Weapons Systems, or AWS/TN-87/001, What's Hot and What's Not. A Practical Guide to the Tactical Decision Aid.

Weather Sensitivities of PGMs and TASs

Before looking at weather sensitivities of PGMs and TASs, we need to understand the difference between active, semiactive, and passive systems (see Figure 3). By active, we are mainly talking about laser designator systems whereby the aircraft delivering the PGM uses a TAS to acquire the target and then focuses laser energy on it. The sensor in the PGM then "sees" the reflected laser energy and guides the bomb to the target. On the other hand, with a semiactive system, someone other than the aircraft carrying

the PGM designates the target with a laser beam. The designator could be another aircraft (fixed wing or helicopter) or a ground level laser designator. The third category, passive systems, depend on having sufficient inherent target/background contrast, either in visual terms of black and white, or in terms of infrared temperatures.(1:3-4) In any case, weather affects the target scene a little different for each system.

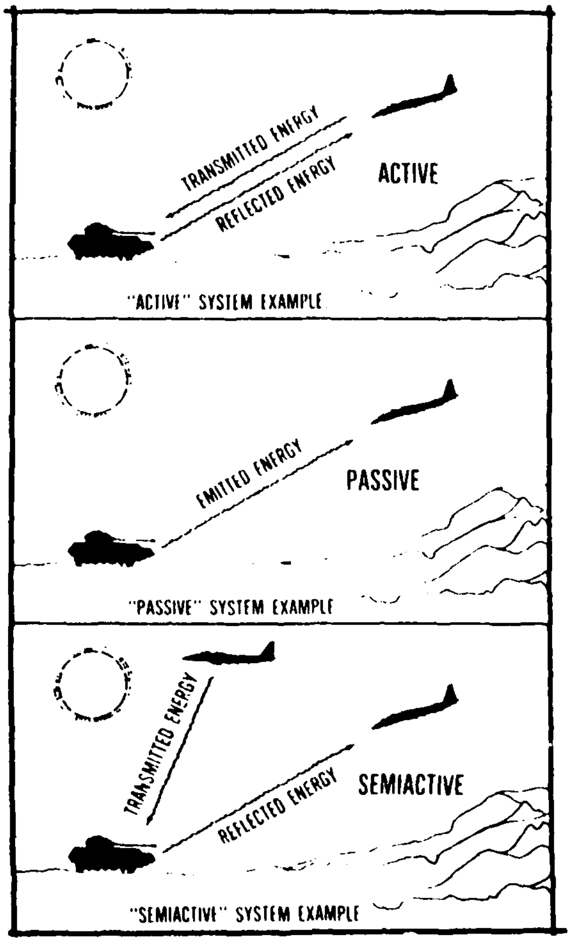

Figure 3. Active, Semiactive, and Passive System Examples.

As shown in Figure 4, there are three factors we need to consider when discussing weather effects on PGMs/TASs. They are the target scene, the atmosphere between the target and PGM/TAS sensor, and characteristics of the PGM/TAS.(1:1)

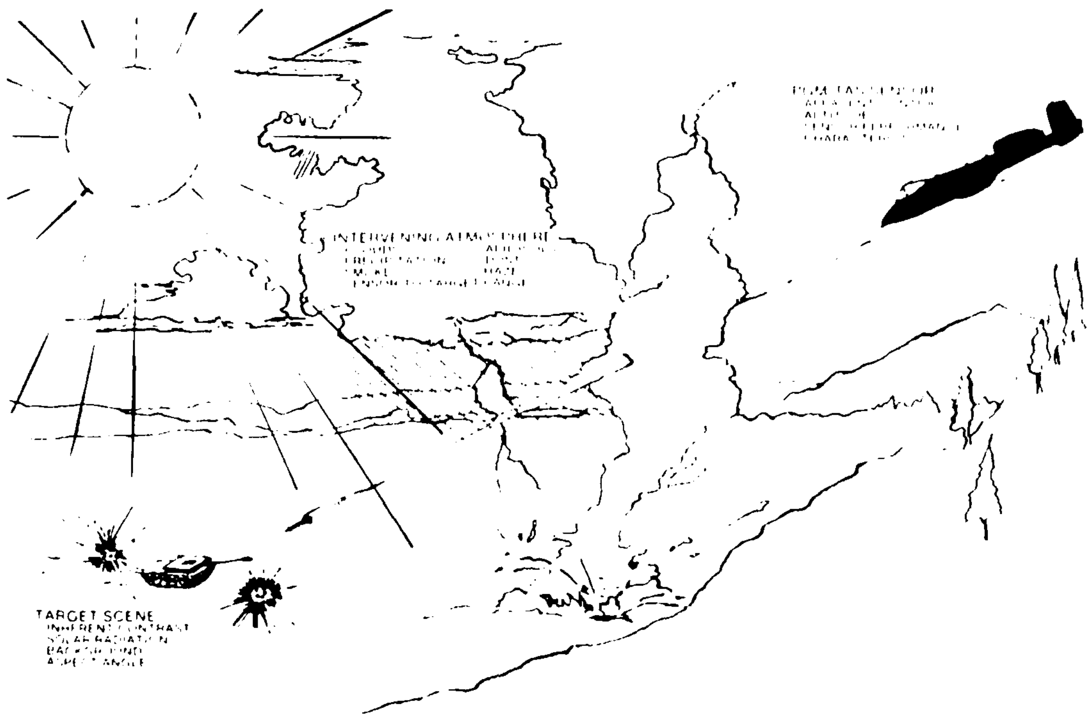

Figure 4. Weather Effects on the Employment of E-O Weapons.

Weather effects on the target scene for active or semiactive systems are relatively minor due to the high intensity of the laser designator. The primary problem will be smoke or fog in the target area that will diffuse the laser energy such that the sensor in the PGM will lose sight of the laser spot. At this point the bomb becomes unguided

and will most likely miss the target. Thus, wind speed and direction are important, because the aircraft must approach from the proper direction to minimize the effect of drifting smoke in the target area. To prove this point, I discovered in my discussions with sources at AWS that the wind forecast created a problem for the crews who flew the Eldorado Canyon raid on Libya in 1984. Because the wind forecast was 180 degrees in error, smoke and dust were not blown away from the target area, but were instead blown into the path of follow-on aircraft. The same situation would have been just as critical for passive systems.

In the case of passive systems, the weather effects on the target scene can be more dramatic. For example, on a cloudy day, the amount of sunlight available to illuminate the target (visual) or to heat the target up (IR) will be limited. Also, precipitation tends to bring the temperature of the target and background closer together and thus reduces the thermal contrast which can wash out the target scene. On the other hand, smoke, fog, and haze have less of an effect on IR systems, but will have significant effects on visual target acquisition systems.(1:2-4) All weather phenomena in the atmosphere between the PGM or TAS platform and the target need to be considered.

As can be seen in Figure 3, the intervening atmosphere can have the greatest effect on the performance of PGMs and TASs. The reason is that no matter what kind of PGM or TAS

you use, transmitted or reflected energy has to pass through the intervening atmosphere where the energy intensity can be reduced by attenuation. In the case of laser energy, you experience a doubling of the effect. First, the laser energy is attenuated before it reaches the target, then the reflected energy is attenuated as it passes back through the atmosphere to the sensor in the PGM. In the case of passive systems (especially IR systems), the effects of weather are less dramatic.(1:6) Now that we understand how weather affects precision guided munitions and tactical acquisition systems, it will be necessary to summarize the effects of weather on these systems.

Table 2 summarizes some of the effects of weather elements on PGM/TAS sensors. By examining Table 2, we can see that as the wavelength of the PGM/TAS sensor decreases (from microwave on the one end to visible on the other), the resolving power of the sensor increases. This means the lower the wavelength of the sensor, the easier it is for the sensor to "see" the target. On the other hand, we can see that the lower the wavelength, the more sensitive the sensor is to interference by atmospheric conditions.(1:7) We begin to see that determining weather effects on precision guided munitions and tactical acquisition systems can be a complicated business.

Table 3 shows the sensitivities of the IR systems due to several weather elements.

TABLE 2. Significance of Adverse Weather Elements and Sensor Resolution as Functions of Sensor Wavelength Category.

<table>
<tr><td rowspan="2">WAVELENGTH CATEGORIES</td><td rowspan="2">MICROWAVE</td><td rowspan="2">MILLIMETER</td><td colspan="4">INFRARED</td><td rowspan="2">VISIBLE</td></tr>
<tr><td>FAR FAR</td><td>FAR</td><td>MIDDLE</td><td>NEAR</td></tr>
<tr><td>WAVELENGTH/ FREQUENCIES</td><td>10cm-1cm 3GHz-30GHz</td><td>1cm-0.1mm</td><td>0.1mm-15μm</td><td>15μm-6μm</td><td>6μm-2μm</td><td>2μm-0.74μm</td><td>0.74μm-0.4μm</td></tr>
<tr><td>RESOLUTION</td><td colspan="7">USUALLY INCREASES WITH DECREASING WAVELENGTH</td></tr>
<tr><td>WEATHER SENSITIVITY</td><td colspan="7">GENERALLY INCREASES WITH DECREASING WAVELENGTH</td></tr>
<tr><td>CLOUDS & FOGS</td><td colspan="3">CAN BE SIGNIFICANT</td><td colspan="4">EXTREMELY SIGNIFICANT</td></tr>
<tr><td>DRY AEROSOLS</td><td colspan="3">INSIGNIFICANT</td><td colspan="2">SIGNIFICANT</td><td colspan="2">EXTREMELY SIGNIFICANT</td></tr>
<tr><td>PRECIPITATION</td><td colspan="2">SIGNIFICANT</td><td colspan="5">EXTREMELY SIGNIFICANT</td></tr>
<tr><td>ABSORPTION</td><td colspan="2">SIGNIFICANT</td><td colspan="3">CAN BE EXTREMELY SIGNIFICANT</td><td colspan="2">EXTREMELY SIGNIFICANT</td></tr>
<tr><td>SCATTERING</td><td colspan="3">SIGNIFICANT</td><td colspan="4">EXTREMELY SIGNIFICANT</td></tr>
</table>

Table 3. Weather Sensitivities of Infrared Systems.
N = Negligible; S = Significant; E = Extremely Significant

	MOLECULAR ABSORPTION			MOLECULAR SCATTERING		
	VISIBLE	INFRARED	MMW/MW	VISIBLE	INFRARED	MMW/MW
Low Absolute Humidity	N	S	N	S	N	N
High Absolute Humidity	N	E	S	S	N	N

	AEROSOL ABSORPTION			AEROSOL SCATTERING		
	VISIBLE	INFRARED	MMW/MW	VISIBLE	INFRARED	MMW/MW
Dry Haze	N	N	N	S	S	N
Wet Haze	S	S	S	E	S	N
Dust	N	N	N	E	S	N
Fog	E	S	S	E	S	N
Thin Clouds	S	S	N	E	E	N
Thick Clouds	E	E	S	E	E	S
Precipitating Clouds with High Liquid Content	E	E	S	E	E	S
Drizzle	S	S	S	S	S	S
Rain	S	S	S	E	S	S
Snow	S-E	S-E	S-E	E	E	S

Further information is available in Appendix A which contains a detailed summary of weather effects on E-O sensors(1:13). By combining the significance of elements from all sources, we can get an idea of the combined effects of weather on PGMs and TASs. This information is summarized in Table 4, and gives us some idea of which atmospheric elements are the most important to the employment of PGMs.

Table 4. Significance of Combined Effects on PGMs and TASs.

	Millimeter/ Microwave	IR	VIS(TV)
Temperature	N	E	N
Dewpoint Temp	N	S	N
Visibility	N	E	E
Cloud Amounts	S	E	E
Cloud Heights	S	N	E
Temp 3 Hours Before TOT	N	E	N
Wind Speed	N	N	S
Precipitation	E	E	E
Absolute Humidity	N	E	N

N = negligible; S = Significant; E = Extremely Significant

In summary, we see that the most significant weather elements that affect PGMs and TASs in the target area are: visibility; cloud amounts; and precipitation. These are followed in importance by: temperature; cloud heights; temperature 3 hours before TOT; and absolute humidity (only for imaging infrared (IIR) systems like LANTIRN and IIR Maverick). The key here is that the Air Weather Service has the capability to provide quality forecast for all of these

weather elements, which in turn means we can provide quality weather information to use in TDA programs.

The Current TDA Computer Program

In the 1970s, AWS was involved in a series of tests where Air Force fighter bombers employed a number of IR Maverick missiles against a variety of targets under controlled conditions. The results of these tests demonstrated that weather had a significant effect on the employment of the IR Maverick and led to the development of the computerized IR and TV tactical decision aid programs. This program is still in use today to support the employment of PGMs. We've already seen how weather affects PGMs and TASs, so now lets take a look at what a TDA is, and what information can be provided by using the TDA program.

Figure 5 depicts the basic models contained in the TV

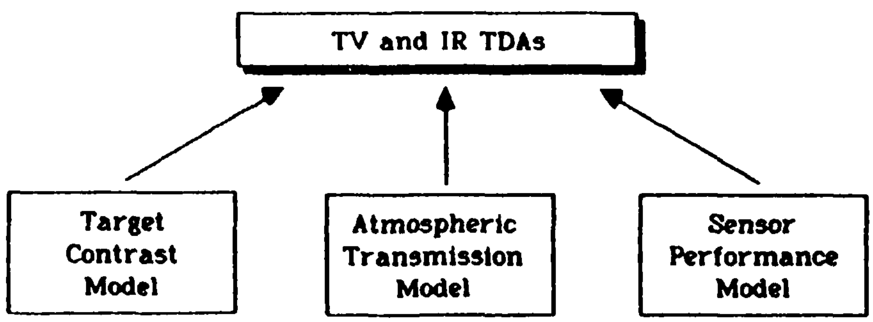

Figure 5. Structure of the TDA Program.

and IR TDA programs(6:2). If you refer back to Figure 1, you can see that each model in Figure 5 addresses a separate part of the overall problem identified in Figure 1: the target scene; intervening atmosphere; and the PGM/TAS sensor characteristics.

The first model, target contrast, gives an estimate of the difference in visual or IR temperature contrast between the target and its background. "It is this contrast that the weapon or acquisition system 'sees'."(6:2) As you will also see later, the target contrast model for the IR systems requires different weather inputs than the TV model. The next model in the program addresses atmospheric transmission.

The atmospheric transmission model determines how well energy (visible light, laser, or IR temperatures) is transmitted through the atmosphere from the target scene to the PGM/TAS sensor. "The atmosphere can severely degrade system performance simply because it washes out the target signal."(6:2)

The third model in the program takes into consideration sensor performance. This model basically provides an estimate of the range at which the PGM/TAS can see the target contrast and lock onto the target.(6:3) This part of the tactical decision aid uses the results of the other two models which are driven by weather inputs. It is precisely this output in terms of acquisition and lock-on

ranges that drives the tactics used to attack a target with a PGM.(6:7-8) Now, however, we need to examine what weather elements in the target area are needed to feed data to the TDA program.

Weather data in the target area needed to run the TDA program includes: temperature; dewpoint temperature; cloud amounts; cloud heights; 24 hour high and low temperature; temperature 3 hours before time over target (TOT); wind speed; and precipitation(6:16). Only the 24 hour high and low temperatures are observed data and do not require a forecast. The rest of the elements are all forecasts of the weather expected in the target area at TOT. But what other data are needed to run the TDA program?

Table 5 shows all the inputs required to run the IR TDA program.(6:28) Those elements identified by an asterisk are the forecast weather elements, and those with a double asterisk are the ones that have the greatest impact on the results of the TDA based on model sensitivities. Likewise, Table 6 shows the inputs required for the TV TDA program.(6:60) The outputs from both programs are basically the same in terms of acquisition and lock-on range.

Before we go any further, lets review what we have learned. The weatherman currently has a microcomputer program that requires a great deal of input data, but will provide estimates of acquisition and lock-on ranges for PGMs

Table 5 Microcomputer TDA Inputs. (IR)

Input	US Units	Metric Units	Data Type	Remarks
Sensor ID			I	System Data
Range Option			I	System Data
Detection Method			I	System Data
Clutter Level			I	System Data
Sensor Height AGL	hft	hft	I/R	System Data
Target ID			I	Target Data
Operating State			I	Target Data
Aspect Angle	deg	deg	I	Target Data
Background ID			I	Target Data
Latitude	deg	deg	R	Met/Site Data
Longitude	deg	deg	R	Met/Site Data
Date			I	Met/Site Data
Time over Target (TOT) GMT			I	Met/Site Data
Elevation MSL	hft	km	I	Met/Site Data
General Background ID			I	Met/Site Data
Maximum Temperature 3 hours prior to TOT**	F	C	I	Met/Site Data
Minimum Temperature 3 hours prior to TOT	F	C	I	Met/Site Data
Temperature 3 hours prior to TOT **	F	C	I	Met/Site Data
Low cloud amount **	8ths	8ths	I	Met/Site Data
Low cloud height **	hft	hft	I	Met/Site Data
Middle cloud amount **	8ths	8ths	I	Met/Site Data
Middle cloud height *	hft	hft	I	Met/Site Data
High cloud amount *	8ths	8ths	I	Met/Site Data
High cloud height *	hft	hft	I	Met/Site Data
High cloud density * (1=thin,2=thick)			I	Met/Site Data
Visibility **	mi	km	I/R	Met/Site Data
Aerosol Index *			I	Met/Site Data
Precipitation Category **			I	Met/Site Data
Rain Rate **	in/hr	mm/hr	I/R	Met/Site Data
Temperature **	F	C	I	Met/Site Data
Dewpoint *	F	C	I	Met/Site Data
Wind Speed **	kts	kts	I	Met/Site Data
Inversion Height *	hft	hft	I	Met/Site Data
Upper Layer Air Temperature *	C	C	I	Met/Site Data
Upper Layer Dewpoint *	C	C	I	Met/Site Data

Data Type: I indicates integer input; R indicates real input.

hft = hundreds of feet; deg = degree of angle; mi = miles
F = degrees Farenheit; C = degrees Celsius; kts = knots
8ths = number of eighths of sky covered by type of cloud;
km = kilometer; in/hr = inches per hour; mm/hr = millimeters per hour

Table 6 Microcomputer TV TDA Inputs.

Input	Us Units	Metric Units	Data Type	Remarks
Sensor ID			I	System Data
Range Option			I	System Data
Sensor Height AGL	hft	hft	I/R	System Data
Target ID			I	Target Data
Percentage			I	Target Data
Target Length	m	m	I/R	Target Data
Target Width	m	m	I/R	Target Data
Target Height	m	m	I/R	Target Data
Background IDs				
Background Slope	deg	deg	I	Target Data
Slope Direction	deg	deg	I	Target Data
Aircraft Heading	deg	deg	I	Target Data
Target Heading	deg	deg	I	Target Data
Latitude	deg	deg	R	Met/Site Data
Longitude	deg	deg	R	Met/Site Data
Date			I	Met/Site Data
Time over Target (TOT) GMT			I	Met/Site Data
Elevation MSL	hft	km	I	Met/Site Data
General Background ID			I	Met/Site Data
Overcast Cloud Type **			I	Met/Site Data
Overcast Cloud Height **	hft	hft	I	Met/Site Data
Visibility **	mi	km	I/R	Met/Site Data
Aerosol Index *			I	Met/Site Data
Temperature *	F	C	I	Met/Site Data
Dewpoint *	F	C	I	Met/Site Data
Inversion Height *	hft	hft	I	Met/Site Data

and TASs. However, the maximum acquisition and lock-on ranges produced by the TDA program are quite conservative. Therefore, ..."Observed ranges will normally exceed the

forecast ranges for identical weather conditions."(6:46) Therefore, we have another reason for giving planners the maximum and minimum acquisition and lock-on ranges to use--especially when we are working with forecasts in the 24-36 hour range. Any future TDA programs will need to include the capability to provide these maximum and minimum ranges.

Future TDA Computer Programs to Support the ATO

In late 1986, General Donnelly, then CINCUSAFE, proposed that command and control (C2) computer systems of the Tactical Air Forces (TAF) be used for processing electro-optical TDAs (EOTDAs). By Tactical Air Forces , we refer to all commands worldwide that employ tactical aircraft, like USAFE, the Pacific Air Forces, etc. During a personal discussion I had with General(Ret) Donnelly at the Air War College on 18 January 1989, I asked him why he supported the idea of running EOTDAs on the TAF C2 computer systems. He said that during a meeting in the planning stage for the Libya raid, a navigator weapon system officer asked what the thermal crossover time would be. Since General Donnelly didn't know what the WSO was talking about, he asked for an explanation. The weapon systems officer explained that as the temperature decreases in the desert at night, there is a time (thermal crossover) when the target and background temperatures are so close that you cannot "see" by using an IR TAS. This meant that the raid had to

go either well before the thermal crossover time or well after it. Following the raid, General Donnelly got together with his staff weather officer and delved into the problem of weather support associated with tasking PGMs in the ATO. After learning more about the problem, he wrote the letter to TAC proposing that EOTDAs be developed and that the TAF integrate the program into their C2 computer systems.

Air Weather Service and TAC have known for some time that more accurate weather data will "improve target destruction per sortie, decrease aircraft/aircrew attrition, and decrease cancellation/abortion/diversion of missions." (2:9-19) In addition, AWS has a validated program that is funded by the Air Force for a system called the Battlefield Weather Observation and Forecast System (BWOFS). BWOFS is composed of two distinct subsystems. The first subsystem is a battlefield weather data acquisition system called Pre-Strike Surveillance and Reconnaissance System (PRESSURS), which states a requirement for various types of sensors to be employed in the area of operation to collect target weather data necessary for the judicious employment of PGMs and TASs. The other subsystem is composed of the computer programs that will use the PRESSURS data and produce the Electro-Optical Tactical Decision Aids (EOTDAs) used to support the tasking of PGMs and TASs in the ATO process. In fact MAC, SAC, and TAC have all jointly supported the need for EOTDAs and agreed that EOTDAs are vital to "the

successful allocation and employment of TAF resources, resulting in lower exposure/attrition and higher kill rates."(7:1) Unfortunately, due to recent budget cuts AWS lost funding for the PRESSURS subsystem, but retained funding for the EOTDA subsystem. Although loss of the PRESSURS portion of BWOFS will result in a degraded system, the development of the EOTDA program is still vital to the ATO process. Thus on 30 September 1988, AWS developed a Program Management Plan (PMP) for Automated Electro-Optical Tactical Decision Aid Development.

The PMP calls for the Air Force Geophysics Laboratory (AFGL) to develop EOTDAs to run on the USAFE C2 computer systems. This is a test for further development of EOTDAs to run on all TAF C2 systems. In addition to the AFGL effort, AWS has tasked the Air Force Global Weather Central (AFGWC) to develop an EOTDA weather data base from the output of AFGWC's Advanced Weather Analysis and Prediction System (AWAPS). This data base will be in the same format as data bases used in the Automated Weather Distribution System (AWDS), which will be fielded throughout AWS in the early 1990s.(8:2) The EOTDA weather data base will be produced as output from the AFGWC Relocatable Window Model (RWM) which is a high-resolution, three dimensional model that provides data in a window 1500 x 1500 nm with a grid spacing of 25 x 25 nm. Given the size of the window, the number of data elements at each grid point, and the grid

spacing, the data base will contain approximately 1 megabyte of data.(7:4) This is significant because a data base of this size could easily be transmitted via standard communications links from AFGWC to the user.(8:16) Since the RWM is a relocatable model, AFGWC can position it to produce data for any region of interest in the world. For all this to work, there must be a capability for AWS to provide quality weather data.

SECTION IV

WEATHER SERVICE CAPABILITIES

Historical Weather

The Environmental Technical Applications Center (ETAC) is the Air Weather Service agency responsible for providing solutions to problems that require the use of historical weather data. The result of ETAC analyses can give planners an idea of what kind of weather to expect in an area of operation anywhere from a couple of weeks to months in the future. Therefore, ETAC programs play a key role in supporting contingency planning where weather is a factor.(10:II-5) In addition, historical weather data can play an important role in determining the applicability of employing E-O weapon systems during contingency operations, like the Eldorado Canyon raid or Urgent Fury, the capture of Grenada. ETAC scientists have come a long way in providing this capability.

A group of scientists at ETAC used 10 year's worth of weather data to study the variation in atmospheric transmittance (which can be related to "seeability") of IR weapons. This was for a slant range of 2.5 miles, at a sensor height of around 400 feet, and for the locations shown in Figure 6.(11:1) The results of the study indicated the... "relative frequency of occurrence for bad to good transmittance values revealed a strong bimodal distribution

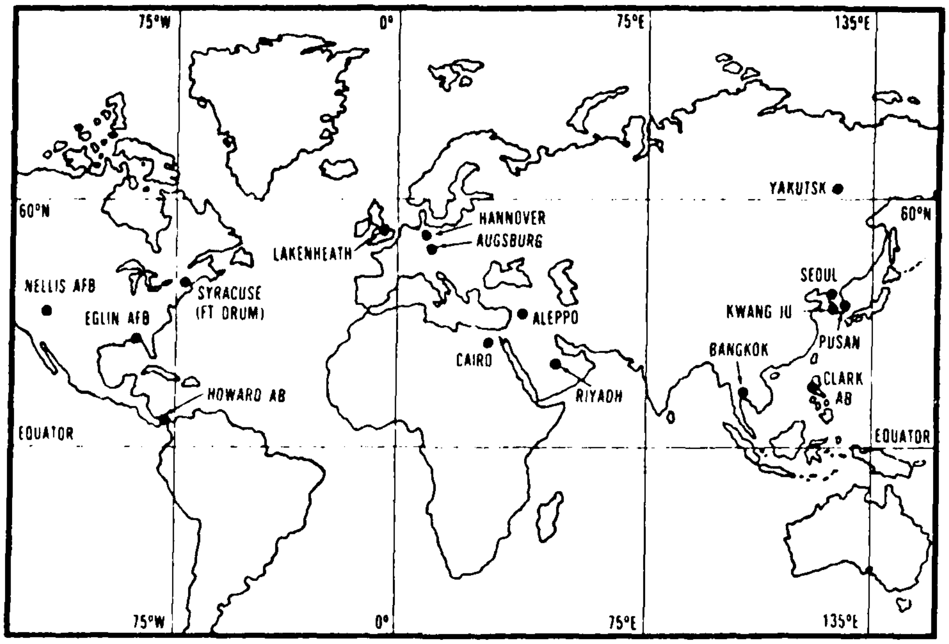

Figure 6 Station Locations

Stations, Location Data, Periods of Record, and Coastal Classification by Region.

	LATITUDE	LONGITUDE	TYPE OF REPORT	PERIOD OF RECORD	WITHIN 50KM OF COAST AND NO COASTAL MOUNTAINS?
EUROPE:					
Augsburg, GE	48°26'N	010°56'E	Synoptic	1973-1983	No
Hannover, GE	52°28'N	009°42'E	Synoptic	1973-1983	No
Lakenheath, UK	52°24'N	000°34'E	Synoptic	1973-1983	No
KOREA:					
Pusan	35°11'N	128°56'E	Metar	1973-1983	Yes
Kwang Ju	35°07'N	126°49'E	Synoptic	1973-1984	No
Seoul	37°33'N	126°48'E	Metar	1973-1984	Yes
MIDDLE EAST:					
Aleppo, Syria	36°11'N	037°13'E	Synoptic	1973-1983	No
Cairo, Egypt	30°08'N	031°24'E	Synoptic	1973-1985	No
Riyadh, Saudia Arabia	24°43'N	046°53'E	Synoptic	1977-1984	No
TROPICS:					
Bangkok, Thailand	13°44'N	100°36'E	Synoptic	1973-1984	Yes
Clark AB, PI	15°11'N	120°33'E	Metar	1973-1984	Yes
Howard AB, Panama	8°55'N	079°36'W	Synoptic	1973-1985	Yes
OTHER:					
Nellis AFB, NV	36°14'N	115°02'W	Airways	1973-1984	No
Eglin AFB, FL	30°29'N	086°32'W	Airways	1973-1983	Yes
Syracuse, NY	43°07'N	076°07'W	Synoptic	1973-1984	No
Yakutsk, USSR	62°05'N	129°45'E	Synoptic	1973-1983	No

(a distribution with two maximum values of transmittance) in the data for mid-latitude cold seasons. Transmissivities (a measure of the ability to see through the atmosphere) were either grouped around their higher values (as a function of dewpoints) or were skewed toward very poor values (as a function of the frequency of occurrence of fog or precipitation)."(11:168) What this all means is that the weatherman in a given theater of operation can use the results of this study to provide preliminary guidance to combat planners about when are the best and worst times for trying to employ IR weapons. Subsequently, another group at ETAC studied the variation in transmittance in the Persian Gulf region and discovered similar results. The results could also be applied to planning for a contingency in that region. Based on the success of these studies, ETAC has initiated a program to produce E-O related historical weather studies for Southwest Asia and Northeast Africa, Central America and the Caribbean, Europe and the Mediterranean Sea, and Northeast Asia and the Northwest Pacific.(11:30) These studies should provide more complete data to augment the output from current and future weather models.

Current Weather Models

In 1985, Air Force Global Weather Central (AFGWC) took a major step forward in terms of advances in military

weather forecasting when they implemented their Advanced Weather Analysis and Prediction System (AWAPS). This system runs on a Cray MXP super computer, the fastest, most capable scientific computer in the Air Force. AWAPS is composed of three interdependent models: the High Resolution Analysis System (HIRAS); the Global Spectral Model (GSM); and the Relocatable Window Model (RWM) that I discussed earlier.(13:1-1) It would be appropriate to address each of these models in turn and discuss how the analyses and forecasts they produce impact the capability of Air Weather Service to provide ATO weather support. The first model we need to consider is HIRAS.

HIRAS produces the analyses that in turn provide the input data for the GSM and RWM forecast models. Thus, HIRAS is important because the output of the forecast models (GSM and RWM) is only as good as the input data from HIRAS. The key to improvement in the analyses provided by HIRAS is the method used to assimilate the weather observations taken everywhere in the world. Lets start by looking at the grid spacing of HIRAS and the way data are interpolated to fit that grid.

All weather models require that input weather data be provided in a specific gridded array. The problem with this requirement is that weather observations taken around the world which HIRAS will analyze don't come arranged in a gridded array. Therefore, HIRAS must first determine what

the meteorological parameters are for each grid point in the analysis array. HIRAS accomplishes this task by using the superior optimum interpolation (OI) technique developed by the National Meteorological Center (NMC). To keep things simple, suffice it to say that OI produces weather data at each grid point by using a scheme that gives the most weight to the observations that are the closest to that grid point. The OI scheme also considers the accuracy of the instruments used to take the observation and the expected accuracy of the first guess of weather data at the grid point.(13:4-1) To top it off, OI is a 3-dimensional system that looks at weather data above and below the grid point, as well as the data in the horizontal plane containing the grid point. In addition, the "first guess" and analysis fields are constantly evolving, which means that in areas where there are many weather observations, the analyses produced by HIRAS are very reliable.(13:4-7) The bottom line here is that the GSM receives very good, reliable analyses in the areas we are primarily concerned with, Korea and Europe.

The Global Spectral Model was also developed by NMC and provided to Air Force Global Weather Central. This means AFGWC received a proven, reliable forecast model to use as the heart of Advanced Weather Analysis and Prediction System.(13:5-1) The reason GSM is the heart of AWAPS is because the output from the GSM drives every other forecast field produced by AFGWC. Therefore, the strengths and

weaknesses of the GSM affect the weather data fields that weather support units receive and use to provide weather advice to their customers. Consequently, an understanding of the major elements of the
GSM is needed.

Lets begin by looking at the horizontal and vertical resolution of the GSM grid, because the grid spacing of a model determines the maximum size of the weather features the model can predict. The horizontal grid of the GSM is on the order of 200 nautical miles (nm) in the north-south direction, and about 250 nm is the east-west direction. The model resolution in the vertical varies logarithmically as you increase in altitude. However, in the lower portion of the atmosphere where we need most of the data to support aircraft operations, data layers are the most concentrated (five layers in the lower 30,000 feet).(13:5-2) The map in Figures 7 shows the grid resolution in Korea. Next, lets look at the GSM production cycle.

The GSM runs on a 6 hour production cycle, which means that every 6 hours, the GSM produces a new, updated set of forecasts for the next 4 days. The problem is that by the time the production cycle ends and the forecasts are produced, the initial weather data that fed the model are also 6 hours old. We will see how this impacts the support to the air tasking order later, but for now lets examine the strengths and weaknesses of the GSM.

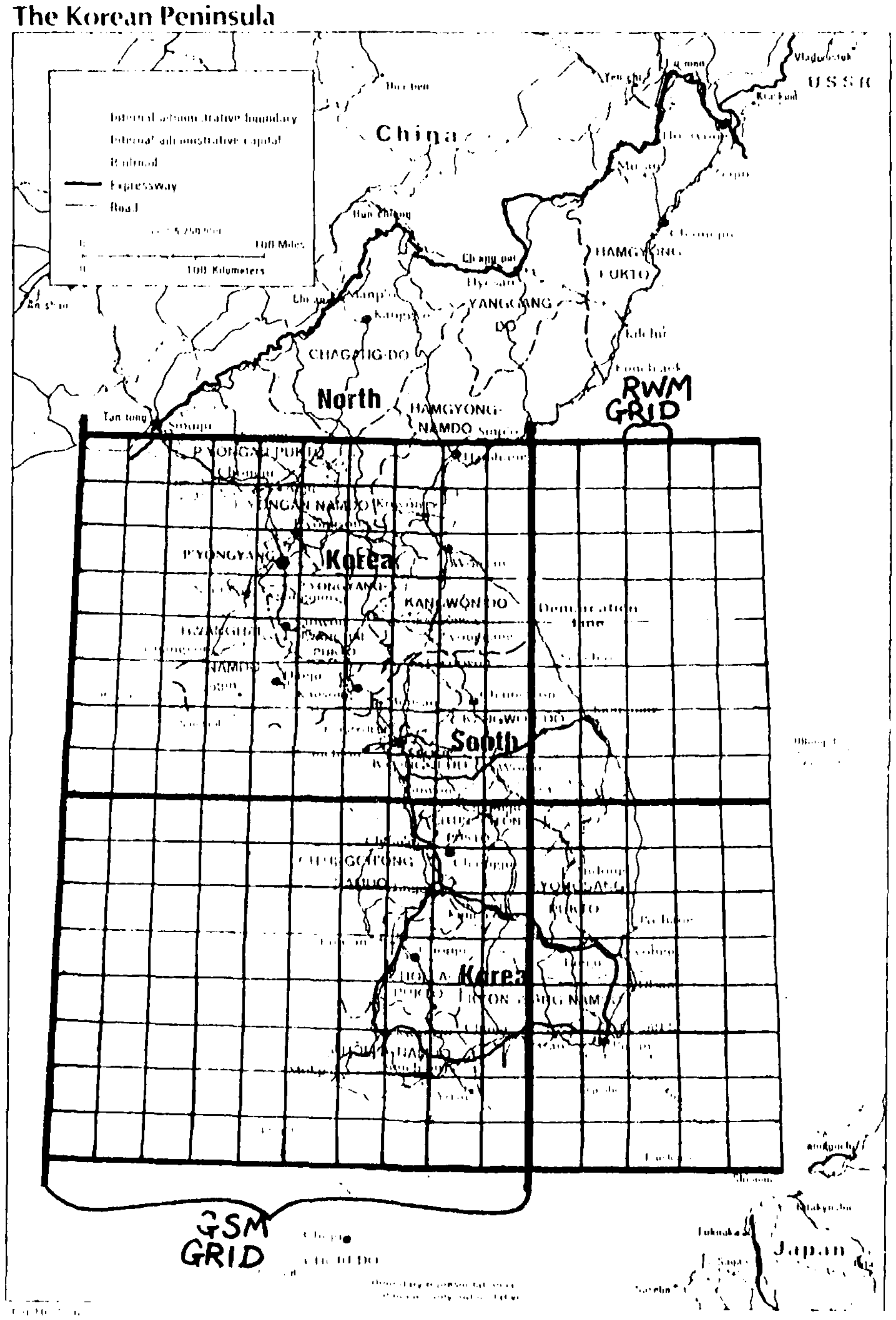

Figure 7. Comparison of GSM grid (thick lines) and RWM grid (thin lines)

The strengths of the GSM are:

(1) The GSM is a global model and thus there are no artificial conditions that introduce errors like in the older weather models.

(2) The GSM contains the latest computer schemes that reproduce weather elements provided by atmospheric processes like condensation (clouds and fog), precipitation, and changes in temperature.

(3) The wind forecasts produced by the GSM are significantly better (20 percent improvement in the accuracy of the jet stream winds, and a commensurate improvement at all levels outside of the jet stream).(13:5-13) Thus the GSM winds are much more accurate and reliable than winds from the older models.

The weaknesses of the Global Spectral Model are:

(1) The GSM does not include three physical processes (radiation, soil moisture, and sensible heat from land surfaces) and therefore has a warm bias in temperature forecasts produced.(13:5-13)

(2) The moisture forecasts in the model tend to be very conservative and under forecast moisture. We'll see later how we can overcome these weaknesses in the model and provide improved weather data to the combat planners during the ATO process.(13:5-13)

Theater Weather Support Unit Capabilities

In this section of the paper I will only address the capabilities of the 7 AF Weather Support Unit (WSU), which was under my command in the Republic of Korea. Nevertheless, the capabilities of other theater WSUs worldwide are very similar.

Currently, the weather support provided by the 7 AF WSU is primarily done manually by using handmade products. In fact the weather information available in the 7 AF WSU today, as I mentioned previously, is much the same as I worked with in Vietnam over 17 years ago. The only real difference is a more responsive, computerized Automated Weather Network that provides the basic weather data to each theater from Air Force Global Weather Central. However, the Air Weather Service has collected data to determine the ability of weathermen to forecast ceilings, visibilities, and precipitation. The results of the AWS analysis indicated that the weatherman in the WSU has the capability to provide very good, reliable forecasts for the most important weather elements that affect precision guided munitions and tactical acquisition systems.(10:III-10) In addition, I had my forecasters in the 7 AF WSU making forecasts for these weather elements that covered the time period of 24 to 96 hours. We found that we could do a credible job of forecasting the weather in the first 72 hours of the forecast period.

The WSUs of today also have microcomputers available to

assist them in providing weather support. But, the only computer program available to assist the weatherman in supporting the air tasking order process is the microcomputer version of the Tactical Decision Aid program used to support flight crews employing individual PGMs. Although weathermen in the WSU could use the TDA program to support the ATO, the resulting workload would be very manpower intensive and time consuming. Here's why.

Based on work done by weather experts at Eglin AFB, it takes 3-5 minutes to run an individual TDA for a PGM with a single set of input data.(6:3) For the weatherman to give the combat planners the information they need, the maximum and minimum acquisition and lock-on ranges for each target,it would take at least 5-6 minutes to run the TDA program per target candidate. The shorter additional time is based on the fact that you only have to change a small portion of the original data for the second run. If the ATO contained the estimated MINIMUM number of targets (75) for Korea, the weatherman could need as much as 375-450 minutes or 6.25-7.5 hours to do the job. If we compare this time requirement with the ATO timelines in Figure 1 of Section II, we can see where the problem lies. The most time available to the weatherman is 6 hours from the target development step to the interdiction/OCA step. And remember, this is for the smallest estimated number of target cases. For the worst case of 150 targets (or more),

the time required to do the job could double. In either case, using the existing TDA computer program as a manual solution is unacceptable unless the vast majority of target weather is either very good or very bad. This would decrease the number of targets that need TDAs and a manual method might work. However, when this is not the case a manual method cannot meet the timelines of the ATO process. Therefore the most acceptable solution with the least risk, is to develop the target and weather data bases together with a program to produce the necessary output for the weatherman and the planners. Then it is a matter of the weatherman and the planners working together to produce the final PGM portion of the ATO. For this plan to work, we will have to rely on future weather service capabilities

Future Air Weather Service Capabilities

The first capability I will discuss is the Automated Weather Distribution System (AWDS) that will be available to AWS units in the early 1990s. AWDS will basically modernize the weather station by eliminating all of the paper products in today's weather station. Instead, AFGWC will produce weather data bases that will contain all of the weather information available from the computer analysis and forecast models. The data bases will then be sent to the weather station where the resident AWDS hardware and software will be able to provide the weatherman a complete

array of analysis and forecast products. These products can also be tailored to support the weatherman's customers. However, the basic grid spacing of the data base data will be 200x200 nm, which is too coarse to support the EOTDA program. On the other hand, the AWDS can be used as a backup to other communication systems in the event that the higher resolution output from the Relocatable Window Model can't be sent to the WSU.(8:2)

High Resolution Weather Model Output

The final Advanced Weather Analysis and Prediction System model we need to discuss is the Relocatable Window Model (RWM). The RWM is important because it is the highest resolution model available anywhere. It can also produce weather data on a grid spacing that is more desirable for use in producing Electro-Optical Tactical Decision Aids. In addition, the RWM basically models the same physical processes and produces the same basic forecasts as the Global Spectral Model. The difference is that the RWM provides output data on a grid spacing of 25 x 25 nm. If you look at the map in Figure 7, it shows the difference between the GSM and RWM grids. The spacing of the RWM weather data is much better for feeding the EOTDA programs. Also, the RWM has the same strengths and weaknesses as the GSM, since it is basically a derivative of the GSM. Finally, the cloud forecasts in RWM are currently produced

by the five layer cloud model, which uses the wind forecast to basically move cloud patterns into the future. The resulting cloud forecasts are produced on the same 25 x 25 nm grid as the RWM.(13:6-1,6-2) The key point to consider here is that wind forecasts from the GSM are much improved, and therefore, so too are the cloud forecasts from the five layer model.(10:III-10)

Future Historical Weather Programs

In my discussions with scientists at ETAC, the only future programs they are pursuing to support the planning process are the regional transmittance studies similar to the ones discussed earlier. These studies will be useful to the weatherman in providing long range planning information to the combat planners in a given region, especially for IR systems like LANTIRN.

In summary, scientists of the Air Weather Service have produced valuable historical weather studies that shed a new light on the long term planning for the employment of PGMs and TASs. In addition, the new weather models running on the super computer at the Air Force Global Weather Central eliminate many of the errors that plagued earlier weather models. Furthermore, the output from these new, higher resolution models is better suited to support future AWS programs like the Automated Weather Distribution System and Battlefield Weather Observation and Forecast System. In

the final analysis, AWS has a greater capability to provide weather information to combat planners today and in the future. Obviously the entire system has and will improve, but what ideas could be implemented now to ensure proper weather information is there to support the ATO process?

SECTION V

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

In Section II, we analyzed the ATO cycle and discussed the types of weather products the weatherman could give the planners. Lt Col Hawse and I concluded that the best method of supporting the planners was to give them a range of weather conditions to include: (1) the best and worst ceiling condition expected in the target area (e.g. best ceiling will be 6,000 feet and the worst 3,000 feet); (2) the best and worst surface visibility in the target area (e.g. best visibility will be 4 miles and the worst 2 miles); and (3) based on those and other atmospheric conditions (discussed in Section III), the maximum and minimum acquisition and lock-on ranges for the types of PGMs that may be employed. This way the planners could look at the ranges of conditions and quickly be able to identify targets that definitely could and could not be attacked by using PGMs. Then after carefully culling out the "for sure" target situations, the planners could concentrate on the remainder of the targets. In addition, the planners should meet with the weather people to discuss the marginal target candidates just prior to finishing the INT/OCA portion of the ATO. At this meeting, the weatherman can give their estimation of the degree of confidence they have in the

best/worst conditions to help the planners with their decisions.

We saw in Section III that PGMs and TASs are significantly affected by weather conditions, and that the most significant target weather elements were: visibility; cloud amounts; and precipitation. Other important weather elements were: temperature; cloud heights; temperature 3 hours before time-over-target; and absolute humidity. In addition, we concluded that AWS forecasters have the capability to provide reliable forecasts of these weather elements. We also determined in this section that weather forecasters in the weather support unit (WSU) do not have enough time to use the current tactical decision aid program to generate detailed weather information for combat planners. In addition, we learned that the Tactical Air Forces have stated a requirement to receive EOTDAs and integrate them into their ATO operations.

It was also brought out that AWS has a plan to develop the EOTDAs to run on the TAF command and control systems and will have the capability in the mid-1990s to provide the high-resolution weather data base needed to run the EOTDAs in the theater Tactical Air Control Center (TACC). However, the EOTDA will basically only provide the same output that we get from today's TDA program in terms of "maximum target acquisition and lock on ranges for PGMs; target acquisition range and polarity for imaging systems; and maximum

designator and/or receiver range for laser systems."(8:4) In addition, the plan calls for the combat planners to receive an output stating whether the conditions are good, marginal, or unsatisfactory for the employment of PGMs for each target candidate. The problem here is that the good, marginal, or unsatisfactory output will be based on predetermined thresholds of the information quoted earlier.(9:5) It is here that the AWS plan comes in conflict with the analysis Lt Col Hawse and I did. If you cannot state unambiguous thresholds for good and marginal, because the thresholds change based on the threat in the target area, how can you determine whether the resulting output of the EOTDA defines good or marginal conditions?

It was shown in Section IV that AFGWC has the most sophisticated models in existence which produce reliable weather data fields needed to support the running of the TACC's EOTDAs. However, the output of the models have weaknesses that could significantly affect the results of the EOTDAs. Therefore, it is imperative that the weather officers in the weather support unit have the capability to look at the model output and modify the data base by using their own more current weather observations. In addition, the WSU will have current weather satellite information to use in refining the timing and movement of weather features and cloud forecasts in the weather data base. The capability to modify weather data bases of the type we are

talking about exists today at the Air Force Global Weather Central (AFGWC). Therefore, the techniques used at AFGWC to modify data bases can be transferred to theater WSUs. Finally, by having to stay on top of the weather to modify data bases, weather people in the WSU will be able to provide better advice to the combat planners when the weather or tasking situations are questionable. Finally, whether it be man or machine or both, what is the best way to provide weather information for Air Force planners?

Based on my experience over the last 2 years in Korea working with the output of the GSM in terms of forecast weather maps, I am convinced the GSM produces forecasts that are vastly superior to the older models. I base this assessment on my 20 years in the weather business and my PhD studies in meteorology. In addition, my experience over the last 20 years providing weather support to a wide variety of customers has convinced me that we must keep a human link in the process and not rely upon computers to make all of the decisions. Only a weatherman can compensate for the weaknesses in weather models and bring regional expertise to bear on weather problems encountered in either the model output or in real time support. The weatherman also provides expert backup when the "computer is down."

Recommendations

1. Air Weather Service and the Tactical Air Forces (TAF) must continue to pursue programs that will result in EOTDAs becoming operational on the TAF command and control computer systems in each theater. After all, we can't afford to squander these valuable resources by not adequately planning for their employment during the ATO process.

2. Air Weather Service should ensure the Air Force Geophysics Laboratory develops an EOTDA program that will provide maximum and minimum acquisition and lock-on ranges based on weather elements included in the weather data base. Such a program will ensure that both the weatherman and the combat planners have the best information at their disposal to use in making critical decisions on the tasking of PGMs and TASs.

3. Air Weather Service should ensure that the target weather data base sent to a theater is structured such that the weathermen in the WSU can modify the data base to include maximum and minimum ceilings and visibilities. These maximum and minimum conditions are needed to produce the range of acquisition and lock-on ranges by the EOTDA.

4. AWS should develop a training program for weather people in theater WSUs. The expertise necessary to develop the training program exists at the Air Force Global Weather Central, where weather sections specialize in analyzing and modifying high-resolution cloud forecasts produced by weather models.

5. Air Weather Service should develop an interim EOTDA program that can run on microcomputers currently in the WSU. This EOTDA program should include a rudimentary gridded target weather data base that consists of the most important weather elements which can be loaded manually or from data supplied by the future Automated Weather Distribution System. This EOTDA program could be used to fill the gap between what we have in the WSU today (nothing) and the complete system that is programmed to be operational on the TAF computers in the mid-1990s. Also, given an interim EOTDA program to use, people in the WSU will develop the necessary skills to operate the more elaborate follow-on program. Additionally, the interim EOTDA program would serve as a back-up to the future program in the event that either the TAF C2 system is down, or that the weather data base cannot be sent from the US to the theater.

6. Air weather service should have the Environmental Technical Applications Center develop historical weather studies that address the weather sensitivities of PGMs and TASs other than just the infrared systems.

The bottom line, however, is that the Air Weather Service and its people in the WSU can definitely provide quality weather data to assist the combat planners in making those tough decisions on whether or not to task the employment of PGMs and estimate the effectiveness of TASs in

combat. And finally, by producing a more logical ATO, we will decrease the impact on combat organizations that have to react to changes in the ATO that inevitably will be driven by changes in the weather. However, if we do the job smartly in the ATO from the beginning, I believe weather support can be a combat multiplier, because a smarter ATO means more bombs on target with minimum interference from weather.

APPENDIX A

DETAILED SUMMARY OF E-O SENSOR WEATHER EFFECTS

WEATHER	EYE AND TV	8 - 12 um IIR/FLIR	MMW
Precipitation (drizzle, snowfall)	Due to large precipitation particle sizes relative to radiation wavelengths, strongly scatters ("blocks") visible and IR radiation; absorbs IR radiation; reduces contrast transmission, IR transmittance, and detection range. Degree of reduction is function of particle size and number density, which vary greatly.	Reduces temperature differences (thermal clutter) in target scene increases target discrimination probability for self-heated targets.	Scatters and absorbs microwave radiation. Degree is function of precipitation particle size, number density, and physical state (ice or water); moderate to severe attenuation with heavy rainfall, slight to moderate with moderate rainfall and wet snowfall, insignificant otherwise. Degree of effect varies inversely with wavelength.
High absolute humidity	No effect	Weakly absorbs 8-12 um IR radiation; reduces IR transmittance and detection range.	No significant effect.
Very high relative humidity	Increases aerosol size; hence, enhances aerosol scattering and absorption; reduces contrast transmission, transmittance, and detection range in presence of aerosols.		No significant effect.
Temperature	No effect	Reduces thermal IR emissions from unheated objects; for low temperatures requires greater sensor sensitivity; can increase discrimination probability for self-heated targets. Higher temperature slightly increases water-vapor absorption (for given absolute humidity) of IR radiation; slightly reduces transmittance and detection range. However, low temperature reduces maximum possible absolute humidity.	Very slightly increases microwave attenuation by rain; slightly reduces radar detection range at low temperatures. Temperature inversion can bend energy causing anamalous propagation.
Snow on ground	Increases background luminance; can increase inherent contrast and, hence, detection range; can increase or decrease visual clutter and affect target discrimination probability accordingly.	Can affect thermal scene characteristics in different ways, depending on bare spots, wetness, temperature, clouds, sun, etc.	Absorbs microwave radiation; reduces radar return (clutter, from target background to degree depending on physical state of the snow; increases target discrimination probability.
Wet ground (well vegetated)	Vegetation usually causes low background luminance, hence low inherent contrast (for dark targets) and decreased detection ranges.	Moisture in soil and vegetation reduces background temperature differences (thermal clutter); can increase target discrimination probability for self-heated targets.	Vegetation reflects considerable microwave radiation, increasing clutter and decreasing target discrimination probability. Free water surfaces reflect specularly.

WEATHER	EYE AND TV	8 - 12 µm IIR/FLIR	MMW
Dry ground (sparsely vegetated)	Increases likelihood of dust in the air during combat activity; can, therefore, excerbate aerosol effects (see above) in target vicinity Bare dry ground often has high luminance and thus enhances target-to-background contrast (for dark targets) and increases detection range.	Increases likelihood of dust in the air and, hence, transient reductions of IR transmittance and detection range in target vicinity Enhances thermal clutter; reduces target discrimination probability.	Reflects microwave radiation approximately specularly. Therefore, smooth dry ground reduces clutter returns and increases target discrimination probability, and rough dry ground produces clutter dependent on number and size of roughness elements.
Sky obscured by clouds or fog	Due to intense cloud scattering (essentially complete extinction) of visible and IR radiation, requires operation beneath cloud bases or "between" clouds. Reduces illumination, shadows, and visual clutter of target scene. If shadow is targ attribute, decreases inher t contrast and detection range	Reduces temperature differences (thermal clutter) in natural target scene; increases target discrimination probability for self-heated targets.	No significant effect
Clear sky	Increases illumination, shadows, and visual clutter. If shadow is target attribute increases inherent contrast and detection range. Increases solar enhancement of path luminance in presence of aerosols (see below); reduces contrast transmission and detection range.	By day, greatly increases thermal clutter in target scene; decrease target discrimination probability. By night, causes small increase in thermal clutter. Enhances "reversals" of relative emittances among features of target scene, occurring near sunrise and sunset.	No effect.
Dry aerosol (haze, smog, smoke, dust)	Scatters visible radiation; increases path luminance, reduces contrast transmission; reduces detection range. Degree of effect is function of particle size and concentration; slight to moderate for haze, variable for pollutants (smog, smoke and dust). Detection ranges are generally less than reported visibility.	Weakly scatters and absorbs IR radiation; reduces transmittance; reduces detection range. Effect is insignificant to slight. Detection ranges are generally much greater than reported visibility. If dust is being generated by explosions or vehicles, can cause severe, local, transient reduction of transmittance.	No significant effect.
Moist aerosol (fog, cloud)	Strongly scatters visible radiation, severely reduces contrast transmission and detection range. Visibilities are poor and detection ranges worse. Since particle sizes are nominally large compared to visible wavelengths, degree of effect is mainly a function of particle number density (generally [illegible]).	Scatters and absorbs IR radiation; causes moderate to severe reduction of transmittance and detection range. Degree can vary greatly for fog, depending on fog particle size evaluation as well as number density, generally severe for cloud. Detection ranges can be as poor as visual ranges for large particle fog and cloud.	Weakly scatters and absorbs microwave radiation, causes insignificant to slight reduction in radar transmittance and detection range. Degree of effect is inverse function of radar wavelength (i.e., stronger for shorter wavelengths).

GLOSSARY

AA	Anti-aircraft Artillery
ABCCC	Airborne Command and Control Center
AFGL	Air Force Geophysics Laboratory
AFGWC	Air Force Global Weather Central
AGL	Above Ground Level
ATO	Air Tasking Order
AWACS	Airborne Warning and Control System
AWAPS	Advanced Weather Analysis and Prediction System
AWDS	Automated Weather Distribution System
AWS	Air Weather Service
BAI	Battlefield Air Interdiction
BWOFS	Battlefield Weather Observation and Forecast System
CAS	Close Air Support
C2	Command and Control
DCA	Defensive Counter Air
EC	Electronic combat
E-O	Electro-Optical
EOTDA	Electro-Optical Tactical Decision Aid
EVS	E-O Viewing System
FLIR	Forward Looking Infrared
GLLD	Ground Level Laser Designator
GMT	Greenwich Mean Time
GSM	Global Spectral Model
HARM	High-Speed Antiradiation Missile
HIRAS	High Resolution Analysis System

ID	Identification
IIR	Imaging Infrared
INT	Interdiction
IR	Infrared
KAPER	Korean Report
LANTIRN	Low Altitude Navigation and Targeting Infrared for Night
LGB	Laser Guided Bomb
LTD	Laser Target Designator
MAC	Military Airlift Command
MSL	Mean Sea Level
MULE	Modular Universal Laser Equipment
NMC	National Meteorological Center
OCA	Offensive Counter Air
OI	Optimum Interpolation
PGM	Precision Guided Munition
PMP	Program Management Plan
PRESSURS	Pre-Strike Surveillance and Reconnaissance System
RECCE	Reconnaissance
RWM	Relocatable Window Model
SAC	Strategic Air Command
SAM	Surface-to-Air Missile
SOF	Special Operations Forces
SWO	Staff Weather Officer
TAC	Tactical Air Command
TACC	Tactical Air Control Center

TAF	Tactical Air Forces
TAS	Tactical Acquisition System
TDA	Tactical Decision Aid
TOT	Time-Over-Target
WSU	Weather Support Unit

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